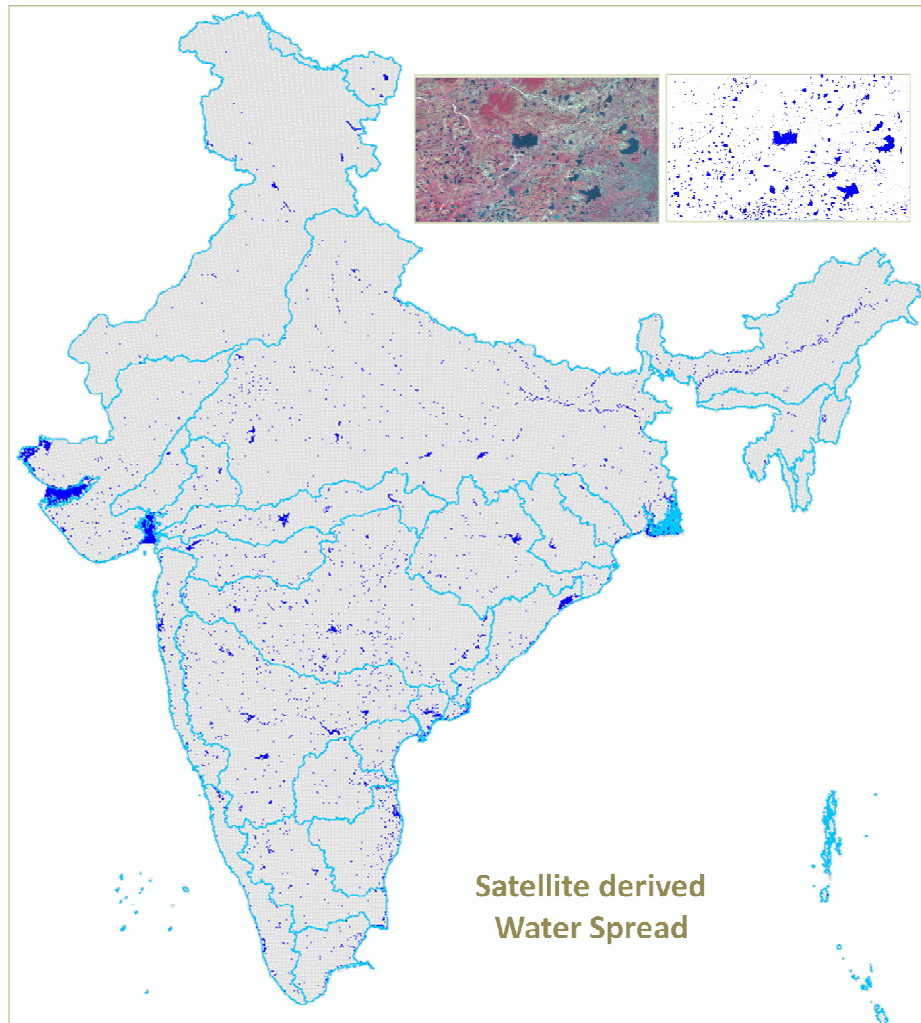


Satellite derived Information on Water Bodies Area (WBA) and Water Bodies Fraction (WBF)



Technical Document

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16	Abstract	A study was conducted to develop a knowledge based hierarchical automated algorithm for quick processing of Resourcesat AWIFS data and extract water bodies information. Water bodies information is used for spatial depiction of water bodies area, water bodies fraction. Technical document describes in brief on concept of using automated algorithm for water feature extraction from Resourcesat-1, Resourcesat-2 AWIFS sensor data. Rule based hierarchical algorithm development, accuracy, limitations, possible applications are summarized in this document .			

Satellite derived Information on Water Bodies Area (WBA) & Water Bodies fraction (WBF)

1. Introduction

Water bodies consists of all surface water bodies viz. reservoirs, irrigation tanks, lakes, ponds, and rivers / streams. There will be variation in spatial extent of these features as a function of rainfall amounts, intensity of rainfall, etc. over season / year. In addition to these surface water bodies, there are other areas representing water surface that may appear due to flood inundations, depression storages in flood plains, standing water in rice crop areas during transplantation stages, etc. These components are seasonal and may exist for small time period (days/weeks). The present study is aimed at automatic delineation of water bodies mentioned in the first category.

Satellite sensors can provide synoptic and dynamic coverage of Earth surface at frequent intervals which facilitates mapping, monitoring of dynamics of surface water bodies. The database hosted in Bhuvan represents water bodies Area (WBA) and Water Bodies Fraction (WBF).

Satellite data utilization for inventory, mapping and monitoring water bodies over larger areas is a popular technique for generation of dynamic databases. ISRO has mapped wet lands at national level in India and atlas was released under Natural Resources Census (NRC) programme. Lenher, et .al, 2004 have created national global lakes and wetlands database. Li et al, 2005 have published maps of Canada's wetlands using optical, radar and DEM data. Ma et al., 2011 published a dataset of China' lakes using Landsat TM/ETM data using Near Infrared (NIR) band thresholds. There are several case studies in literature who have used multi temporal satellite images for delineating water spread area of several reservoirs at high frequency, and estimated the live storage capacity useful for reservoir planning, operations, and sedimentation assessment (Frazer et al. 2000, Sureshbabu et.al., 2003, Manavalan et.al., 1993, Hui, et al.,2008, Sivanapalli, et al, 2010). Normalized Difference Water Index (NDWI) and Modified Normalized Difference Water Index (MNDWI) were used by McFeeters et al., 1993 and Xu, et al., 2006. Subramaniam et al., 2011 developed automated extraction algorithm for delineation of surface water bodies using Indian Remote Sensing(IRS) Resourcesat AWiFS, LISS III data with rule based hierarchical algorithm and implemented on national datasets.

2. Automated Algorithm for extraction of surface water bodies

Overview of methodology : Steps involved in estimating satellite derived Water Bodies (WBA), Water Bodies fraction (WBF) are : acquisition of multi-temporal satellite data,

computation of Top of Atmosphere (ToA) reflectance, implementation of automated algorithm for generating water body layer, quality check and extraction of grid-wise (3'x3') Water Body Fraction (WBF).

2.1. Specifications of satellite data: Mapping and monitoring of surface water area requires satellites /sensors which are capable of having larger swath with higher Repeativity and 56 m spatial resolution. Resourcesat-1/ Resourcesat-2 AWiFS sensor having spectral data in four bands : 0.52-0.59 μm (Green), 0.62-0.68 μm (Red), 0.77-0.86 μm (NIR) and 1.55-1.70 μm (SWIR) is used for the study.

2.2. Development and implementation of automated algorithm: Generally, space-borne multi-spectral digital images are analyzed using supervised/unsupervised classification techniques available in commercial /open source image processing softwares. The parameters for image classification are provided manually for each of the scene and the process is repeated for all. This process is time consuming and manual interpretation is required for identification of thresholds and assigning clusters to water feature class. Automatic algorithm developed by NRSC (Subramaniam et.al, 2011) for quick processing of satellite data was used for generation of a spatial water layers. Automated algorithm is a spectral knowledge driven, developed after spectral characterization and transformation to mathematical relationships viz. band ratios, band thresholds & other combination of relationships across the spectral data of four bands 0.52-0.59 μm (Green), 0.62-0.68 μm (Red), 0.77-0.86 μm (NIR) and 1.55-1.70 μm (SWIR).

The hierarchical logic used for the development of automatic extraction of water bodies are:

- Water has lower reflectance in the Visible-SWIR spectral region compared to other surface cover features ;
- Very high contrast between Green & NIR (except turbid water pixels) and Green & SWIR due to the absorption of NIR & SWIR radiation by water ;
- Reflectance of water in NIR is lower than that of Red band.

The overview of hierarchical, multi-logic algorithm is shown in flow chart (**Figure.1.**) These logics were constructed for execution in a C language for operation implementation. Algorithm is well trained over larger datasets across the country and is scene independent which is operationally used for extracting water feature. Satellite derived water bodies and water bodies fraction is shown in **Figure.2** as an example.

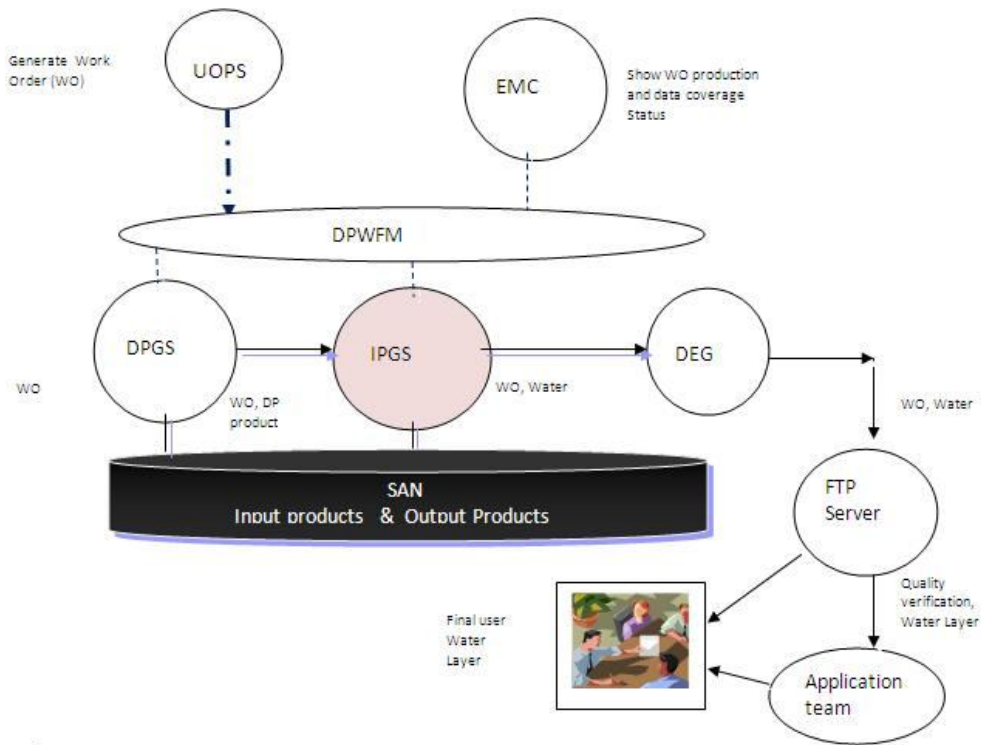
3. Productization in IMGEOS

IMGEOS is a ground segment infrastructure designed as a multi layer architecture having User Services, Data reception & Processing systems and Storage along with Security and Monitoring components to meet the increasing demand of varied types of satellite data products acquired from all IRS Earth Observation missions.

In IMGEOS the data product generation chain is triggered by work-orders from User order processing system (UOPS). The chain comprising of dedicated processing systems controlled by Data product work-flow manager (DPWFM) ,generates products as per the defined processing level .

The Information product generation system (IPGS) is a newly added work-flow in IMGEOS to automatically generate water layers from standard products of Resourcesat-2 AWIFS sensor in near real time .

Every day 1-2 real time passes of AWIFS data covering Indian region are processed in near real time to generate scene based water layers. These scene based layers are used to generate fifteen day composite mosaic of Indian region .

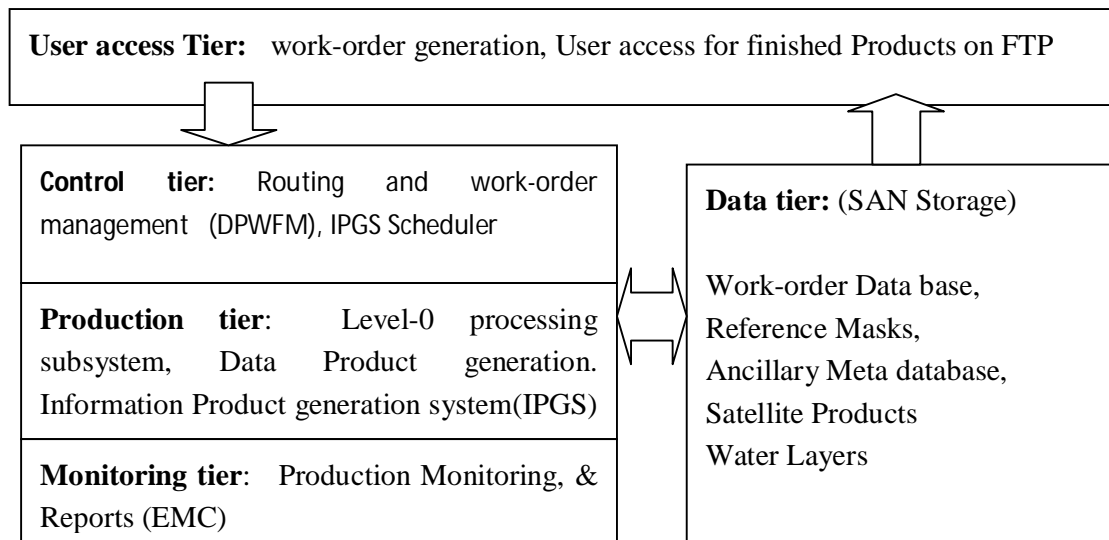


IMGEOS production Flow for IPGS Product Generation and Dissemination

The major elements under IPGS production chain are:

- **Product generation Initiation through Work Order generation:**
IPGS Data processing Chain is initiated with IPGS Work Order generated at User Ordering system. DPWFM routes this work-order to DPGS work-centre to generate terrain corrected products
- **Information Product Generation System :**
IPGS Scheduler at IPGS work-centre processes the scene wise work-orders , invokes and manages the IPGS Layer Generation Software to generate scene wise water layer. Once all scene based water layers of the path are generated the path wise Mosaic generation is initiated. Once in five days all the path wise mosaics are used to generate Indian region mosaic. The three, five day Indian region mosaics are time composited to generate the fifteen day mosaic product.
- **Product Dissemination to FTP:**
The generated water mosaic layers are then transferred to FTP Server via Data Exchange (DEG) system which are downloadable from FTP Server through a FTP user-account.
- **Chain Monitoring and Routing through DPWFM and EMC:**
DPWFM generates status messages of processing done at each work-centre in the chain for the use by EMC software to allow graphical monitoring of progress done in IPGS Chain.

IPGS System and Software architecture:



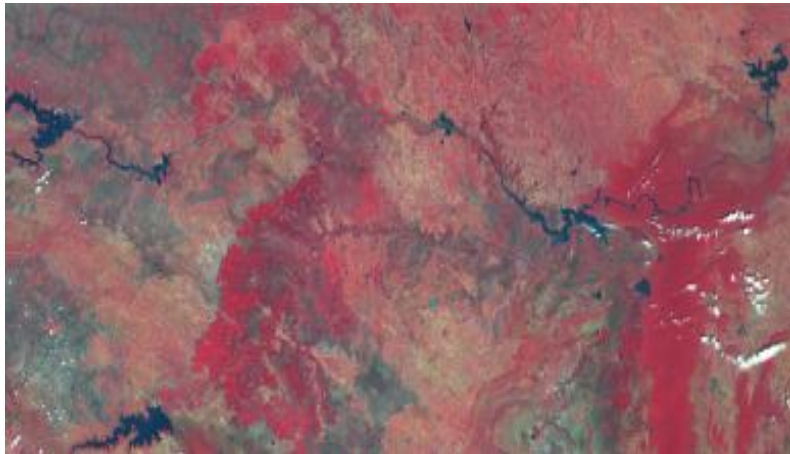
IPGS software is a new component in IMGEOS consisting of Information Layers , Mosaic generation and Scheduler software. The layer and Mosaic generation software is developed and optimized in IMGEOS framework with standardized interfaces for automation and error handling in production chain using open source tools. The synchronization of Mosaic generation and time composition are achieved using system level daemon services. The IPGS scheduler is capable of distributed scheduling to take advantage of available processing nodes.

4. Water bodies Area (WBA) and Water Bodies Fraction (WBF)

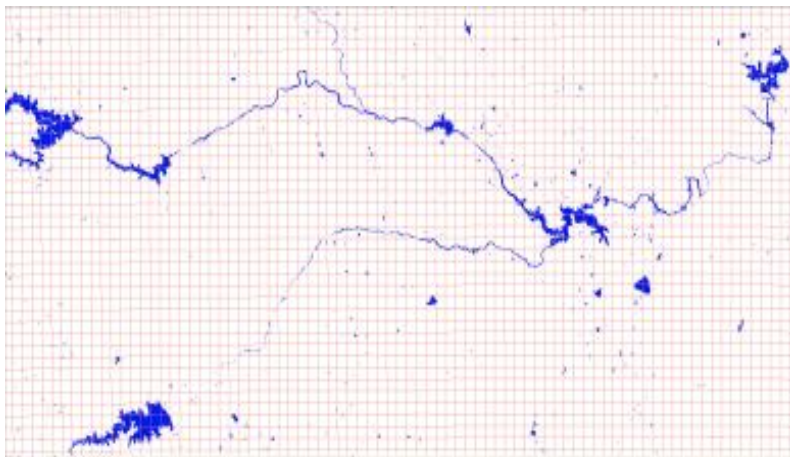
Automated extraction algorithm provides a spatial water layer representing water pixels from each scene after satellite data acquisition. Scene-wise water layers are mosaiced for generation of nation-wide water bodies layer. Water Bodies fraction is defined as fraction of geographical area covered with water bodies and total geographical area. The data base hosted in Bhuvan are spatio-temporal Water Bodies (WB) layers as a 56m resolution image and Water Bodies fraction (WBF) layers on (3' x 3' Grid interval) during last 8 years (2004-05 to 2011-12) representing October, February and May months during Kharif, Rabi and Summer seasons in India. Data on Water Bodies fraction in IDRISI Raster format can be downloaded from Bhuvan.

Products Specification: Water bodies and Water Bodies Fraction

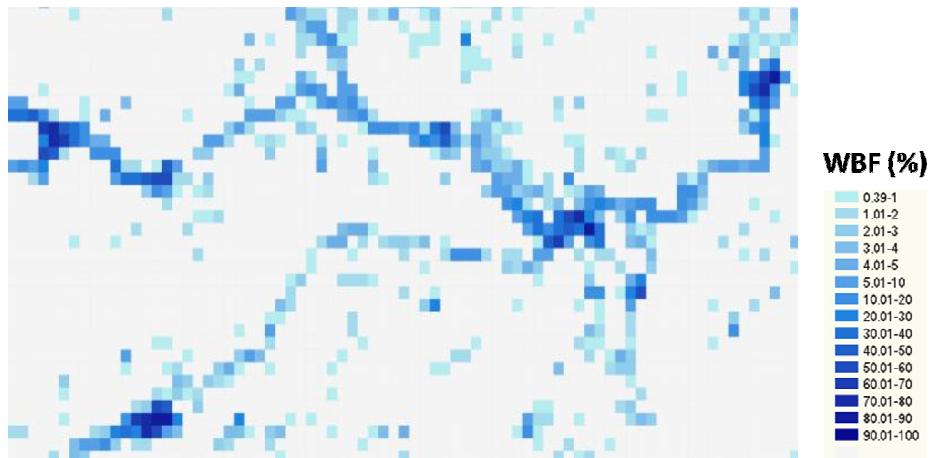
Satellite data processing and Dissemination	
Satellite / Sensor	Resourcesat-2 AWiFS
DN conversion rule	Top of Atmosphere Reflectance (TOA)
Spectral Analysis	Based on TOA reflectance from all four bands of Resourcesat-2 AWiFS
Data processing Algorithm	Knowledge based rules and hierarchical algorithm for quick processing of satellite data
Data processing Chain	Through IMGEOS
Data Dissemination	Through Bhuvan
Deliverables	Water Bodies, Water Bodies Fraction (India)
Image File Format	Geo-TIFF
Projection	Geographic coordinates (Lat., Long.)
Datum	WGS-84
Spatial Resolution	56m
Radiometric Resolution	8 bits per pixel
Correction Level	Terrain corrected
Number of bands	1
Output Image	Water : 1, Non water : 0
Thematic Accuracy	
Water Bodies Area	
Cloud free images	Kappa Coefficient -0.821, Overall accuracy - 93.5%
Partially cloud affected images	Kappa Coefficient -0.801, Overall accuracy - 93.5%



Resourcesat-2 AWiFS Image



Algorithm derived Water Bodies Area (WBA)



Water Bodies Fraction (WBF)

Figure.2. Satellite derived water bodies and water bodies fraction

3. Spatial Database hosted on Bhuvan

Automated Water Bodies Extraction (AWBE) algorithm was integrated into Integrated Multi-mission Ground Segment for Earth Observation Satellites (IMGEOS)- a data acquisition and processing chain . This has been facilitated for near real time satellite data processing and dissemination. This is implemented since 16th Dec, 2013. Resourcesat-2 AWiFS data is being used for this study which has Repeativity of 5 days, and hence fortnight time composite is generated from three time windows of 5 days each. Presently the following water bodies layers derived from 15 days time composite is hosted on Bhuvan and will be continued further.

Year	Month(s)	Source of Satellite Data
2013	16-30 Dec, 2013	Resourcesat-2 AWiFS
2014	01-15 Jan, 2014	Resourcesat-2 AWiFS

In addition to the above, following historic data is also hosted for visualization and observing the trends in surface water bodies dynamics.

Year	Month(s)	Source of Satellite Data
2004	Oct,2004	Resourcesat-1 AWiFS
2005	Feb, 2005, May, 2005 Oct,2005	Resourcesat-1 AWiFS
2006	Feb, 2006, May, 2006 Oct,2006	Resourcesat-1 AWiFS
2007	Feb, 2007, May, 2007 Oct,2007	Resourcesat-1 AWiFS
2008	Feb, 2008, May, 2008 Oct,2008	Resourcesat-1 AWiFS
2009	Feb, 2009, May, 2009 Oct,2009	Resourcesat-1 AWiFS
2010	Feb, 2010, May, 2010 Oct,2010	Resourcesat-1 AWiFS
2011	Feb, 2011, May, 2011 Oct,2011,Nov 11,Dec11	Resourcesat-1 AWiFS Resourcesat-2 AWiFS
2012	Jan, 2012, Feb, 2012, Mar,2012,Apr,2012, May,2012, Sep, 2012, Oct 2012, Nov,2012, Dec,2012	Resourcesat-2 AWiFS
2013	Jan, 2013, Feb, 2013, Mar,2013,Apr,2013, May,2013	Resourcesat-2 AWiFS

4. Accuracy Assessment

Accuracy assessment was carried out with random grid sampling (75 x 75 pixels) representing different geographical regions spread across the country, different time periods. The overall accuracy is found to be 93.5% with kappa coefficient of 0.821

5. Limitations

Presently, optical data sets are used for generation of water bodies. Cloud cover persisting will limit the satellite data acquisition. Presence of hazy cloud, cloud shadows and also resolving land – water boundary pixels limits the accuracy of satellite derived water bodies area. There is scope for using microwave data with development of automated algorithms to improve frequency of data generation and accuracy. Glacial lakes and water bodies are not part of this database. There could be errors due to cloud or non detection of water pixels from the knowledge based automated algorithm and such inaccuracies observed will be considered for updating the knowledge base and improve the automated water bodies extraction algorithm .

6. Possible Applications

- Geo-spatial data based hydrological modeling tools requisite, a systematic spatial frame work for organizing the input database and output products. Such uniform spatial matrix would provide orderly description of spatial heterogeneities of hydrological parameters/variables. Water bodies fraction information at 3' x 3' grid will be useful.
- Facilitates study of water surface dynamics at regional/ river basin/river sub basin level for trend analysis and generate scenario of inter / intra annual / seasonal dynamics.
- Analysis of relationships between regional rainfall scenarios vs. water spread in major, medium reservoirs and status of smaller irrigation tanks. This will help in understanding water storages and utilization across the time periods.
- Inventory, mapping and monitoring of surface water area at frequent interval.

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